17

Diesel Railway Traction

Special Shunting Number

Sleeve-Valve Diesels

FOR the first time in British diesel railway traction, an oil engine embodying sleeve valves has been adopted. The example in question is the six-cylinder four-stroke 150/165 b.h.p. Brotherhood-Ricardo engine fitted to the third Hunslet L.M.S.R. geared locomotive, which is described in another part of this issue. Although the first cost of engines of this type may not be so low as that of the standard patterns, the maintenance charges should be lower as there are no poppet valves requiring periodical examination and grinding. The lack of tappets and rocker gear also makes for silent operation, which is by no means an unimportant point, for the footplate of a diesel locomotive is not as silent as the grave. It may be that those engineers who have been brought up on the normal valve will look askance at a large sleeve with a compound rotary motion, but in addition to providing fewer moving parts this system enables simple, compact and efficient forms of combustion chamber and cylinder head to be fitted. The head, indeed, may be in the form of a forging, thus eliminating the trouble which is sometimes experienced by the cracking of cast units. From the railway point of view, another good feature is that the overall height is somewhat reduced by the elimination of the cam-operated poppet valves, and it is frequently possible to take advantage of this by reducing the height of the engine casing and giving the driver a better look-out. With a standard casing to cover engines of various makes, such as is present in Hunslet locomotives for the L.M.S.R., the lower height of the sleeve-valve engine ensures ample head room for removals.

Fluid Couplings for Shunting Duties

RECENT British examples of diesel-mechanical shunting locomotives are fairly equally divided between the application of friction plate and hydraulic clutches. At first sight it would appear that both types have certain definite spheres, but it is easy to find exceptions to prove the rule. For the smallest type of locotractor, say of 20-40 b.h.p., it seems as if the advantages of fluid couplings are not sufficient to balance the extra cost and bulk, but from 50 b.h.p. upwards the clutch question must be carefully considered. Our own view has been that where the maximum tractive effort must be frequently exerted in starting heavy trains, a fluid coupling is advantageous in that sustained slipping capacity is available, and this enables the train weight to be smoothly and gradually taken up. There are, of course, numerous geared locomotives in which a high percentage of the rated tractive force is frequently taken up and transmitted by a normal friction clutch. In this category we have in mind two geared shunting locomotives at work in the north of England which frequently exert 65 to 75 per cent. of their rated tractive effort, but we are unable to call to mind any instance in which tractors or locomotives of this type regularly exert over 90 per cent. of the rated value. Feats such as those recorded in our issues of January 27 and March 24, 1933, where a 12-ton tractor with an oil engine exerting only 35 b.h.p. started and hauled a 55-axle train weighing 648 tons, could hardly be performed with a normal friction clutch, although equalled with electric transmission.

There is, however, a further advantage to be placed to the credit of the hydraulic clutch, and this was brought home to us recently when attending the trials of a 26-ton six-wheeled shunting locomotive. This is the protection which it affords the engine. On the occasion of the above tests, with the oil engine running at its rated speed of 1,000 r.p.m. and the locomotive travelling in second gear at 4·5 m.p.h., the hand brake was gradually screwed on, and the engine revolutions and road speed brought down until the engine was turning at the normal idling speed. The slippage of the clutch absolutely prevented a further reduction and the stalling of the oil engine. Under these conditions the locomotive was at rest, although the oil engine was turning at 250-275 r.p.m. and the full torque was available.

Diesel Shunting Economy

MUCH of the economy credited to the diesel shunting locomotive is due to the saving in fuel, more to the absurdly low hours of service allowed to equivalent steam engines, and still more to the elimination of one man from the footplate. There are numerous fallacies connected with the above points which are not generally understood, but the superiority of the diesel engine for shunting work of all types is sufficiently great to withstand their exposure. In the first place, it is not the practice to shut down the oil engine during the relatively lengthy stops incident to yard shunting work, and we have recently noted cases where the engine was idled for periods as long as 17 min. This, of course, increases the fuel consumption above the figure which might be expected from a consideration of the time the locomotive is actually moving.

Secondly, there is nothing unusual in a steam shunting engine working 24 hours a day for six days a week. Where the diesel unit scores in this direction is in really intensive service, where the time for cleaning the fire and smokebox, and coaling and watering of a steam locomotive, can ill be spared, and in the longer period over which a diesel locomotive can keep up a 24-hr. performance. It is this latter quality which is almost the key-point of the diesel locomotive's economy, for the high initial cost makes it essential to spread the capital charges over a great number of service hours if a saving is to be shown compared with steam traction.

The third point mentioned above, the elimination of one man from the footplate, is not always possible of attainment. Indeed, so far as industrial shunting is concerned, it is an exception, for the fireman in works or colliery yards is usually more of a shunter than a stoker. Data from a number of diesel shunting locomotives of 150 b.h.p. and upwards with electric and mechanical transmission show that, with present prices, unless the service hours are over 1,400-1,500 per annum, and circumstances permit of the services of one man being dispensed with, it does not, generally speaking, pay to adopt diesel traction.

DIESEL VEHICLE PERFORMANCE

I—L.M.S.R. 150 b.h.p. shunting locomotive

IT is well known that even in what is regarded as continuous service, a shunting locomotive is actually moving considerably less than 100 per cent. of its time, and is engaged in revenue-earning movements to a still smaller degree. Results obtained from different parts of the world show that over the total time in service, diesel shunting locomotives develop approximately 12 to 20 per cent. of the rated engine output. Further, certain authorities allow a mean speed of 6 m.p.h. when considering the mileage covered by shunting machines, whereas the actual figure in railway yards varies from 2·0 to 3·5 m.p.h.

By the courtesy of the L.M.S.R. we recently had an opportunity of observing the work performed by the diesel-mechanical locomotive No. 7402 in shunting service at Hunslet goods yard, Leeds, and some of the results we obtained are given in the accompanying notes and diagrams. This locomotive, which was described in our issue of December 29 last, was delivered to the railway about the turn of the year, and since January 15 has been engaged in 24-hr. service. Although slight teething troubles have caused one or two brief breaks, a mileage of 1,900 has been covered. The normal schedule calls for the locomotive to be available for operation in the yard from 2.0 a.m. on Monday to 6 a.m. on Sunday, and handled each day by three shifts of men. A daily allowance of 45 min. is made for fuelling, sanding, and inspection.

The fuel consumption averages 25 gal. for 24 hr., and if the specific gravity of the fuel be taken as 0·87 and the consumption as 0·43 lb. per b.h.p. hour, the load factor is only 14·1 per cent. Moreover—and this is an important point—it is not the practice to shut down the engine during ordinary stand-by periods, and thus one of the principal reasons put forward by diesel protagonists loses some of its weight. The engine, of course, is run at normal idling speed (in this case the McLaren-Benz engine ticked over very quietly at 325-350 r.p.m.), but the specific fuel consumption is high at low outputs. Keeping the oil engine running throughout the day, apart from one or two allotted inspection periods and at the shift change-overs, appears to be followed in practically every case in this country, but does not seriously affect the economy shown by the diesel locomotive.

At the commencement of regular diesel operation by locomotive No. 7401 in Hunslet yard some eight months ago, several drivers were trained in the operation of diesel locomotives, and they, in their turn, are now teaching further steam drivers how to handle the new form of power. The men, with some months of experience, now operate the diesel units very skilfully, but with new men constantly being trained, it will not be surprising if the two first diesel locomotives show maintenance costs above what might have been anticipated, although No. 7401, which is over two years old and must have about 8,000 hours' work to its credit, is showing no signs of coming trouble.

Except for certain trains at definite times each day, the diesel locomotives are rarely called upon to handle more than 16 wagons at a time—a load of approximately 180-200 tons. During certain tests No. 7402 started and hauled, on first gear over the yard points and curves, 60 mixed goods wagons, say, 675 tons, and then a 40-wagon coal train of practically the same weight. One of the regular duties which calls for a high tractive effort to be exerted for an appreciable period is the haulage out on to the main line every night of a through goods train from Leeds to Carlisle, consisting of 40 mixed wagons and a main-line goods engine, with a total weight of about 650 tons. This is well within both the tractive and horsepower capacity of No. 7402 (even if no assistance is given

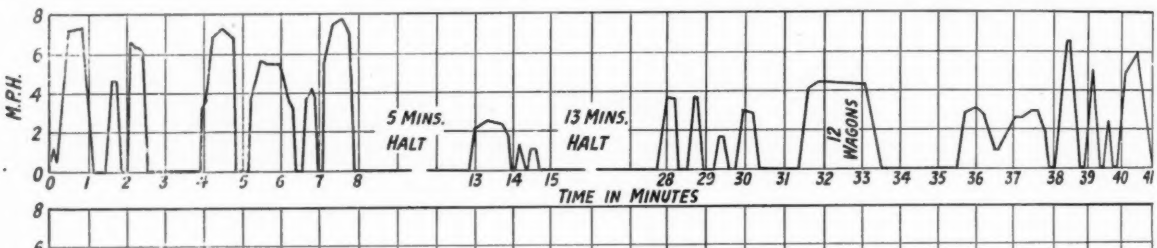
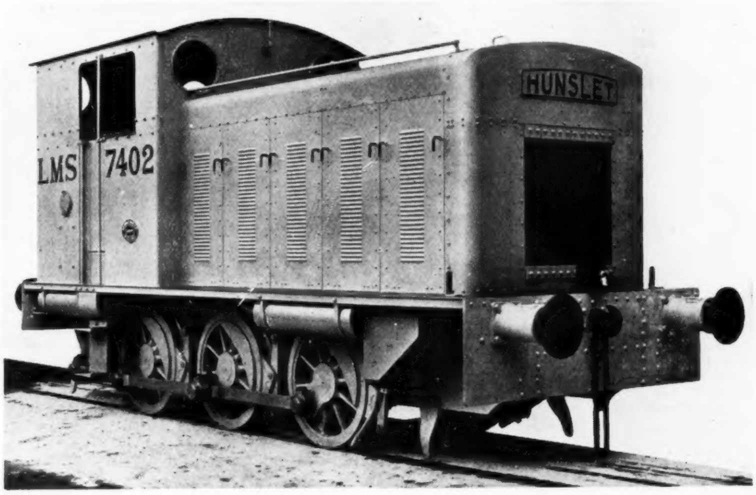


Diagram of normal shunting movements over a period of 100 min.

by the train engine), the required outputs, allowing for yard tracks, being of the order of 5,750 lb. and 70 r.h.p. respectively, but this duty has also been satisfactorily performed by No. 7401, which scales only 21 tons, as against the 26 tons of No. 7402, and has a maximum tractive effort of 9,560 lb. compared with 12,000 lb. The train is hauled out with the steam engine at the back so that it may start straight away in the opposite direction on its main-line journey when clear of the yard.

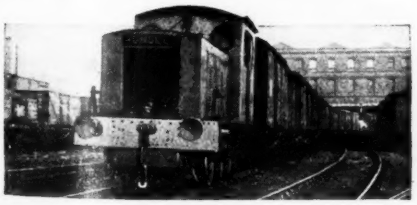
Practically all the work in the yard is done on the first gear step, that is with a maximum speed of 4·5 m.p.h., as may be seen from the accompanying diagrams, which represent our observations as to the time the locomotive was actually moving and at work during 100 consecutive minutes of ordinary shunting work. The amount of work done at speeds below 5·0 m.p.h. at first sight seems to bear out the contention of the builders of this particular locomotive that only two gear steps and a maximum speed of 9-10 m.p.h. are necessary for railway shunting work. But in the Hunslet yard there are one or two occasions during each day in which it is necessary to run light for some 300 or 400 yards on a track which is straight and free from points, and on these occasions the locomotive is not so sprightly as a steam engine would be. There are, of course, other occasions in the same yard when a speed of something like 14 or 15 m.p.h., running light, would be advantageous. Nevertheless, a criterion of the ability of this locomotive to do all the work required of it is found in the fact that no goods train has ever left the yard late as a result of being marshalled by diesel traction.

Starting of the main engine is effected by means of a two-cylinder Scott petrol engine, located in the bonnet, which is itself started by means of pulling up a stirrup in the cab. On the occasion of our visit, the main engine was stopped and started several times for our benefit, and although on one of these occasions a new driver had some trouble in getting the main engine to restart, the men with a few weeks' experience found no difficulty. An interesting comparison was possible here, for the latest diesel locomotive, No. 7403, which is described in another part of this issue, was at the time undergoing final adjustment trials on adjoining tracks. The Bendix gear in this unit is operated by compressed air, and the starting equipment functioned immediately on a number of starts.



150/165 *b.h.p. diesel-mechanical shunter with eight-cylinder McLaren-Benz engine, L.M.S.R.*

There were two further points in the design of No. 7402 which attracted our attention. First, the exhaust from the silencer is led out of the top of the bonnet, without passing up any projecting pipe, yet the exhaust gases never entered the cab, even when the windows and doors were open. This exhaust layout has an additional advantage, in that the gases are always in full view of the driver, who is thus assisted in forming an opinion as to the performance the oil engine is giving. The second point was that although the cab can be completely closed, some provision has been made for heating. This is most desirable, for there is no firebox to provide warmth. The arrangement incorporated in No. 7402, however, seemed to us to leave something to be desired, for a portion of the exhaust is conducted through a small pipe with three return bends, but as this pipe is secured to the underside of the cab roof, its already small heating capacity is further reduced.



150 *b.h.p. M.A.N.-engined shunter at work in Hunslet goods yard, L.M.S.R.*

Dutch Diesel Trains

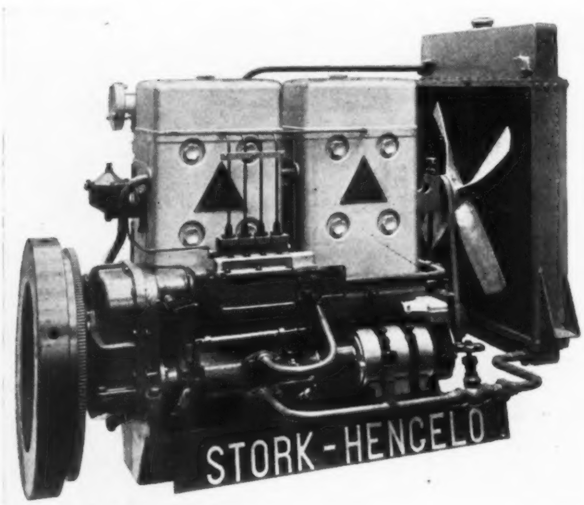
The first 20 of the 820 b.h.p. articulated diesel-electric trains of the Netherlands Railways, which were described in the March 23 issue of this Supplement, are to be put into regular operation on May 15. It is anticipated that the whole order for 40 trains, 35 of which have Maybach engines and five the Stork-Ganz type, will be completed by the end of July. It is the intention to run two of these trains coupled together, thus giving a seating capacity of 320 and a horsepower of 1,640. Until the completion of the whole order, light steam trains will assist in maintaining the full service on the Amsterdam-Utrecht-Arnheim, Utrecht-Rotterdam, and Utrecht-Eindhoven lines.

DUTCH DIESEL TRACTORS

Extension of oil-engined shunters follows two years' satisfactory operation

One of the first two diesel-electric loco-tractors of the Netherlands Railways. Thirteen similar machines are now on order

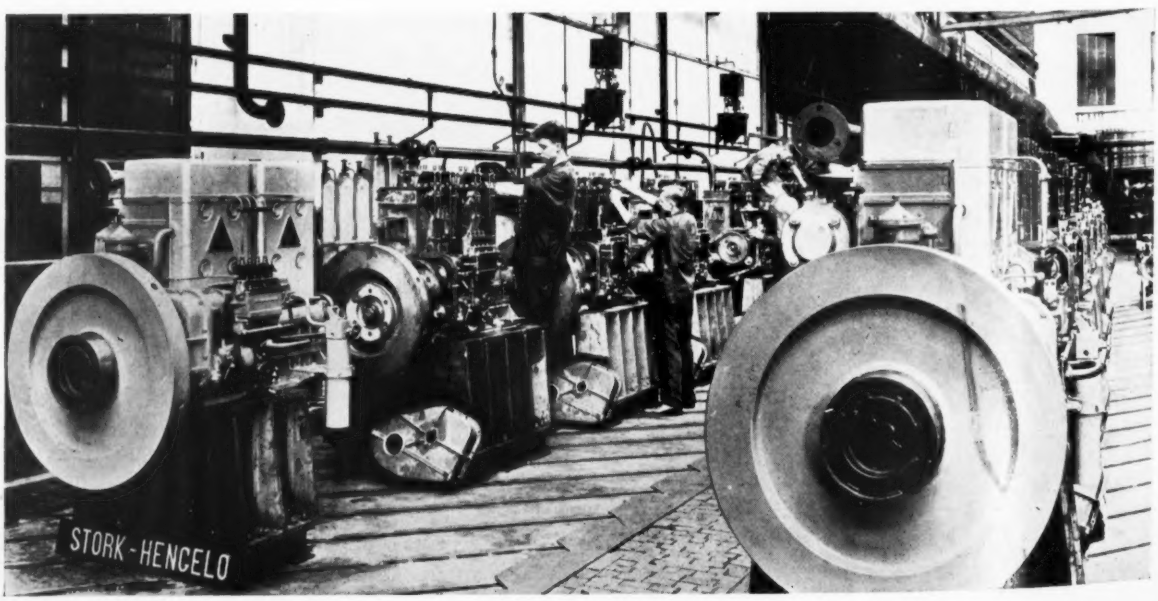
IN addition to the 40 high-speed diesel trains, the Netherlands Railway recently ordered 13 diesel loco-tractors, and these are now in course of delivery. Two years ago, Stork Bros., of Hengelo, delivered two four-wheeled machines with 145/160 b.h.p. eight-cylinder Ganz-Jendrassik engines running at 1,000 r.p.m., and one of them is illustrated at the head of this article. The results obtained with these units decided the railway authorities to extend the practice, but the new tractors are only of 72/85 b.h.p., although, like the two 160 b.h.p. machines, they incorporate electric transmission.



The engines are of the Ganz-Jendrassik type, built under licence by Stork Bros., and have four cylinders with a bore of 150 mm. and a stroke of 185 mm. At the rated speed of 1,000 r.p.m. the brake m.e.p. is 83 lb. per sq. in., and the piston speed 1,215 ft. per min. A pre-combustion chamber is employed, but the atomiser nozzle has an opening of slightly more than one millimetre in diameter, so that no trouble through fouling or choking is anticipated. Owing to the relatively large nozzle, the fuel velocity is low, and this results in less wear of the affected parts. The fuel is forced through the bottom of the pre-combustion chamber to a cam-shaped projection on the cylinder crown, from which the fuel is sprayed in all directions. This projection prevents the fuel jet impinging directly on the flat surface of the piston crown.

A Ganz fuel pump of the spring injection type is fitted, and ensures an atomisation of constant high efficiency over the full speed range, a matter of some importance at starting. The injection pressure is approximately 1,150 lb. per sq. in. A start from dead cold can be made, without the use of pre-heating or an ignition coil, by opening the air valve only towards the end of the suction stroke.

Left: 72/85-b.h.p. Stork-Ganz oil engine
Below: Batch of Stork-Ganz engines under erection



POWER STATION SHUNTING

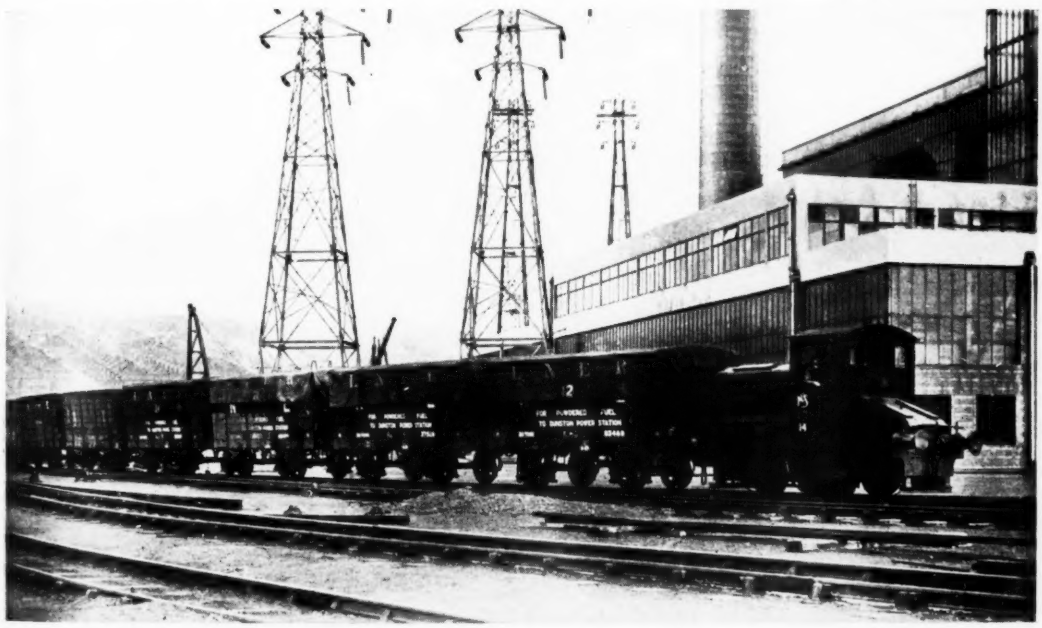
Diesel-electric locomotive handles heavy coal traffic

WHEN the Dunston power station of the North-Eastern Electric Supply Company was enlarged as a result of the Grid scheme, it was considered necessary to increase the stock of shunting engines, and after a series of trials, one of the latest type of Armstrong-Whitworth diesel-electric locomotive was acquired.

This locomotive is the first to be put into service of a range developed as a result of the behaviour in operation of the 15-ton shunter exhibited at the Shipping and Machinery Exhibition, 1933. The main point of difference is that the Scotch yoke drive, with jackshaft between the wheels, has been replaced by a simple rod drive transmitting the torque of a jackshaft located behind the wheels. Power is provided by an 85 b.h.p. six-cylinder Saurer engine direct-coupled to a d.c. generator, and the two machines are housed in a bonnet in front of the cab. The engine cooling water is circulated through a Serck radiator at the front of the bonnet. The motor is in a casing to the rear of the cab, and is directly above the jackshaft, which it drives through gears. The transmission control is of the Armstrong-Whitworth simple A.B.E. type which gives automatic and foolproof operation with a minimum of equipment. A maximum tractive effort, at 25 per cent. adhesion, of 8,400 lb. is provided. At 4·0 m.p.h. this has fallen to 4,500 lb., and at the top speed of 8·0 m.p.h. to 2,900 lb. The weight of the locomotive is 15 tons, the wheels 3 ft. 0 in. in diameter, the wheelbase 5 ft. 6 in., the length overall 19 ft. 4 in., the maximum height 10 ft. 10 in., and the overall width 8 ft. 0 in.

At Dunston power station the locomotive is in service from 7.30 a.m. to 5.30 p.m. from Monday to Saturday, and on Sunday is operated for about five hours. The work consists in handling all the movements of wagons bringing in 3,000 tons of coal a week, most of the wagons being of the four-wheeled type with a capacity of 20 tons. In normal breaking-up work the load rarely exceeds nine 20-ton wagons, a gross load of about 250 tons, but on a test trip the locomotive started and hauled round curves a trailing load of 650 tons. The consumption of fuel when performing these duties amounts to approximately 44 gallons a week. Since going into regular service, with a full sump, ten weeks ago, only two gallons of lubricating oil have been added.

Driving is a simple operation, and control handles are fitted on each side of the cab. The engine control handle has four positions: stop, glow, start, idle. The handle is moved into the " glow " position for a few seconds before starting the engine, and this heats the glow plugs in the cylinder head. Hand and simple air brakes apply blocks to all four wheels, and air sanding gear is provided.



85 *b.h.p. diesel-electric locomotive at Dunston power station*

For locomotives of this type and size, the builders estimate a working cost of just under 20s. for an eight-hour shift. Made up on the basis of coal at 18s. per ton, water at 1s. 0d. per 1,000 gal., and fuel oil at 5½d. per gal., the estimated comparative costs of equivalent steam and diesel shunting locomotives are as follow:

	Steam	Diesel
Locomotive weight, tons ..	18	15
Fuel	6s. 1d.	1s. 10½d.
Water	5d.	—
Lubricants	5d.	6d.
Maintenance and repairs ..	6s. 0d.	5s. 4d.
Wages	15s. 7d.	12s. 0d.
Total cost for 8 hr.	28s. 6d.	19s. 8½d.

In the above estimate the cost of the preparation and washing out of the steam locomotive is included in the wages bill.

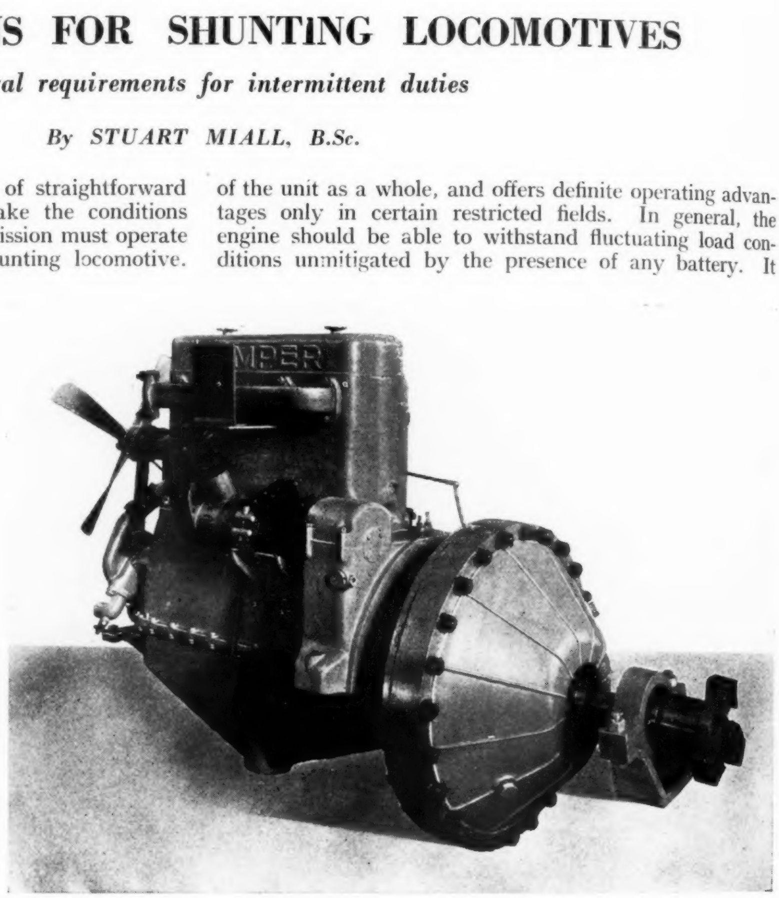
TRANSMISSIONS FOR SHUNTING LOCOMOTIVES

General requirements for intermittent duties

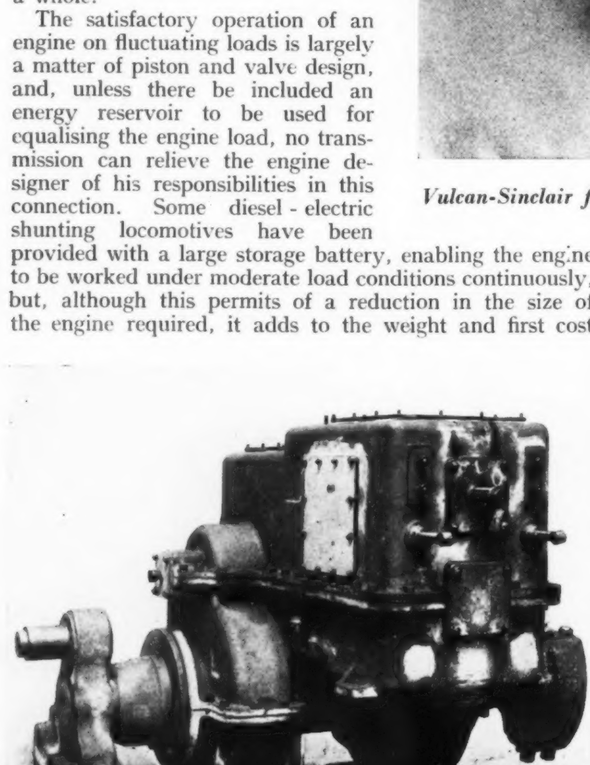
By STUART MIALL, B.Sc.

SHUNTING duties differ from those of straightforward hauling in such a way as to make the conditions under which the engine and transmission must operate a good deal more exacting in the shunting locomotive. Instead of being able to operate under load for long periods, the engine is alternately working at the extremes of no load and close on stalling load. This simplifies the problem of engine cooling, for the average load factor must be low. Also the bearing loads are frequently lightened so that the working parts are given some respite from conditions which might otherwise be extremely arduous. Against this, however, must be set the very frequent alternations of high and relatively low temperature conditions in the cylinders (making for cool and possibly slack fitting pistons and valves) together with a possibility of frequent shock loading of the engine as a whole.

The satisfactory operation of an engine on fluctuating loads is largely a matter of piston and valve design, and, unless there be included an energy reservoir to be used for equalising the engine load, no transmission can relieve the engine designer of his responsibilities in this connection. Some diesel - electric shunting locomotives have been provided with a large storage battery, enabling the engine to be worked under moderate load conditions continuously, but, although this permits of a reduction in the size of the engine required, it adds to the weight and first cost of the unit as a whole, and offers definite operating advantages only in certain restricted fields. In general, the engine should be able to withstand fluctuating load conditions unmitigated by the presence of any battery. It need not, however, be subjected to violent changes in torque loading, for here the difficulty is one which can be overcome satisfactorily in several ways. In the simplest form of transmission, which closely follows standard automobile practice, a friction clutch is used to establish the connection (through a gearbox) between the prime mover and the driving wheels. The engine torque can be developed gradually by careful manipulation of the clutch, or the latter can be provided with a dashpot to ensure gradual engagement irrespective of anything the driver may do. Constant-mesh gears are to be preferred in this type of transmission, gear changes being effected with these by the engagement and disengagement of simple dog couplings with or without synchronising devices.



Vulcan-Sinclair fluid coupling attached to engine of small shunting locomotive



Constant-mesh gearbox and jackshaft

Fluid Couplings

Where the duties of a shunting locomotive are likely to be somewhat heavy at times, the friction clutch should be supplemented with, or be superseded by, a fluid coupling of the Vulcan-Sinclair traction type. Such a coupling can be slipped indefinitely without any wear occurring, and the possibility of a small amount of locally-produced heat buckling or burning any part is completely absent. The heat is produced in the fluid itself, and, as it is distributed through a large volume, the temperature rise is slow. Furthermore, the heat is brought rapidly to the surface of the coupling by the circulation of the fluid and it is safely dissipated to the atmosphere. An advantage of the

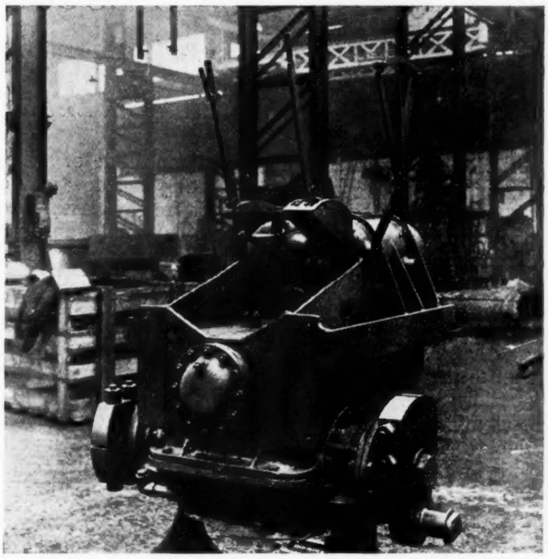
fluid coupling not enjoyed by friction clutches is the constancy of its performance. There are no rubbing surfaces to become harsh or slippery with the ingress of foreign substances, or as the result of faulty adjustments.

Pre-Selective Gear-Changing

Several gearboxes are now available which offer the advantage of gear pre-selection, and enable gear-changes to be made swiftly and without any possibility of clashing. All are of the constant-mesh type with separate clutches for each gear. Such are the gearboxes made by Maybach Motorenbau and by the Swiss Locomotive & Machine Works on the Continent, and by the Wilson-Drewry box manufactured in this country. The Continental boxes have clutches within the gears themselves, but the Wilson-Drewry box, which is of an improved epicyclic design, has a number of band brake clutches surrounding the drums for the different speeds. As each band brake (there are several of them) has comparatively little to do, the Wilson-Drewry gearbox withstands exacting service conditions extremely well, and a fluid coupling, though a desirable addition, does not appear to be altogether necessary. It has, however, been applied in conjunction with epicyclic gears to the latest L.M.S.R. shunting locomotive, which is described on another page of this issue.

Electric Transmission

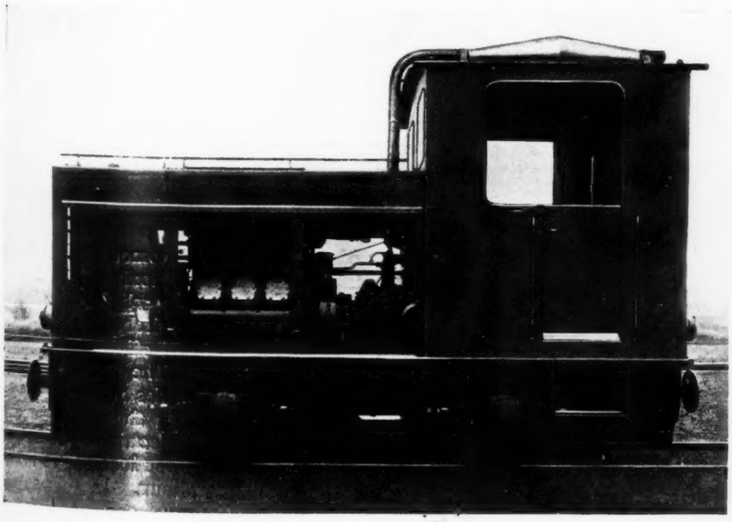
A transmission of unquestioned reliability is the electrical method. For ease of control and for the protection it affords the engine it is still unequalled, though its lead in these directions is becoming steadily less in view of the great improvements being wrought in gear and fluid transmissions. Its disadvantages have been apparent for many years; it is heavy and relatively inefficient, and it is hard to imagine that it could ever be anything but more expensive in first cost than a mechanical or partial hydraulic transmission. Good examples of the latest British practice in diesel-electric shunting locomotives are afforded by the Armstrong-Whitworth 250 b.h.p. machine recently delivered to the L.M.S.R. and by the same firm's 85 b.h.p. unit now at work at Dunston power station. In the latter transmission, the control has been simplified to a point where it resembles the systems common some years back on petrol-electric road vehicles. It is felt, however, that the field for electric transmission is in units of 400 b.h.p. and upwards. Up to the present, mechanical



Gearbox, jackshaft and controls of 90 b.h.p. locomotive for Sudan

systems have not invaded this domain to any considerable extent, although there are one or two main-line locomotives which have given encouraging results.

Fluid transmissions, and especially those using turbine torque converters which can be rendered inoperative after the acceleration period, are proving very successful for railcar and light train work and it is probable that they will be developed for use in shunting locomotives. The Lysholm-Smith converter, developed for use in this country by Leyland Motors Limited, and the Voith-Sinclair converter, are both practicable alternatives to mechanical and electrical transmission, and a great deal more is likely to be heard of them in the future.



Above: 90 b.h.p. narrow-gauge diesel-mechanical locomotive. Right: Four-speed gearbox with outside dry-plate clutches; a compressor for operating the clutches and supplying compressed-air brakes is mounted above the gears

OIL-ELECTRIC LOCOMOTIVES IN STEEL MILL TRANSPORTATION

*By W. L. GARRISON, Locomotive Department, Ingersoll-Rand Company**

RAILROAD yard service covers a multitude of switching movements, from the spotting of a few cars on industrial tracks to the heavier freight classification and inter-yard transfer movements. Steel mill transportation requirements undoubtedly call for many switching movements identical with the average railroad yard; nevertheless, the operating conditions existing in a steel manufacturing plant and a railroad terminal organisation are so vastly different, that each must be considered foreign to the other in the selection of locomotives, and in the performance results obtainable.

Steel mills are primarily interested in the cost of steel products manufactured, and the continuous and uninterrupted flow of material through the plant from incoming raw material to outbound finished products. Rail transportation of material, therefore, is a vital part of the steel-making process, and a department whose cost of operation has been almost entirely predicated on steam locomotive performance, and subject to only slight variation. Oil-electric locomotives now offer a real possibility from the standpoint of cost reduction.

Unfortunately, many steel plants have been built or have grown up through a process of evolution or plant extension, with a minimum consideration of the locomotive requirements and track construction necessary to facilitate economical transportation. This heritage of the past has resulted in many heavy grades, tight curves, too much duplication of locomotive movements between mill departments, and too many bottle-necks in the track layout, where congestion of car movements means serious delay in material haulage. Many of these conditions cannot be changed, due to plant limitations.

In recent years more attention has been given to the steel mill transportation problem, resulting in many improvements. Increasing tonnage movements and the increasing number of 70-ton gondola and hopper cars have added their bit to the task of the steel mill locomotive. With locomotive assignments of three eight-hour shifts per day, 365 days a year, every year, there can be no more exacting test for any locomotive than in the transportation service of a modern steel plant.

Roughly, steel mill service may be segregated as follows:—

1. *Blast Furnace.*
   (*a*) Hot metal and slag handling.
   (*b*) Ore stone and coke haulage.
   (*c*) Miscellaneous.
2. *Open Hearth.*
   (*a*) Charging pan buggies to open hearth floor.
   (*b*) Ingot mould service to soaking pit.
   (*c*) Scrap haulage.
3. *Runabout Service.*
   (*a*) Material haulage between mills.
   (*b*) Miscellaneous.
4. *Classification Yard.*
   (*a*) Incoming material handling.
   (*b*) Finished material, weighing and transfer.

The locomotive requirements for each of these services varies widely in different plants, depending on the size of the mill and local operating conditions. In comparatively small mills using a few locomotives of generally uniform capacity, and in large plants employing a great number of locomotives (ranging in size from a small 4-coupled switcher to a large 8-coupled switcher or Consolidation locomotive), the oil-electric may be used to replace individual locomotives gradually without change of personnel or facilities available. The oil-electric is a self-contained unit, and can be used as such.

Application

In the American Rolling Mill and Donner Steel plants, 300-b.h.p. 62½-ton oil-electric locomotives have replaced 54-68-ton six-wheel switchers of the tender type having tractive efforts of from 30,000 to 38,500 lb. The tractive effort-speed characteristics of oil-electric and steam locomotives are entirely different, due to the constant-power output of the former and the varying power output of the latter, with increasing rolling speed. The oil-electric, due to the greater factor of adhesion characteristics of all electric locomotives, and to the corresponding greater horsepower available at low speeds, has considerably higher tractive power available up to 5-6 m.p.h. than a comparable steam locomotive. Both in railroad and steel mill experiences it has been learned that an oil-electric locomotive will perform most yard switching service with smaller horsepower rating than is required of the steam locomotive.

In general, yard switching service is performed at from 4-10 m.p.h.; on the other hand, heavy transfer service or fast classification yard work requires greater tractive effort at higher speeds. The steam locomotive delivers greater tractive effort with increasing piston speed or rolling speed. To meet this requirement, the oil-electric locomotive must be equipped with sufficient oil-engine power to deliver the higher tractive power at increasing speeds. This has resulted in the development of larger sizes of oil-electric locomotives, and indicates the necessity of a careful survey of mill switching conditions in the selection of motive power.

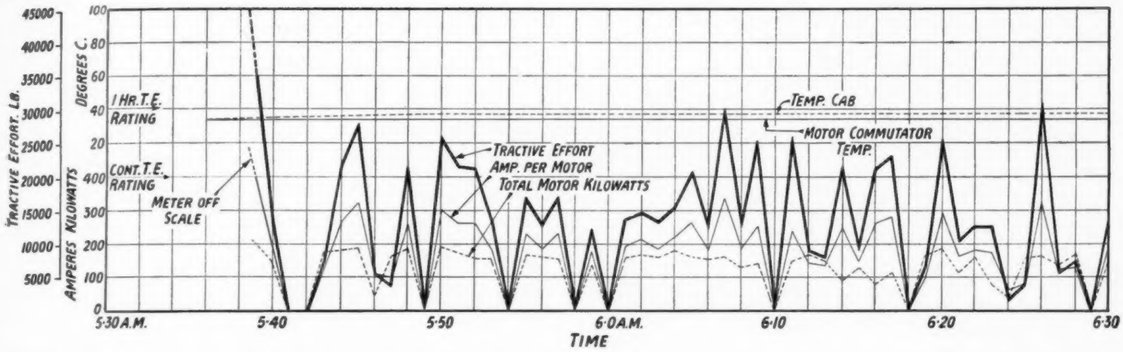
In steel mill service to date, the higher tractive power available at low speed has been of great advantage in starting heavy loads on the level or up grades, placing loads on trestles without taking a long run for them, in spotting and weighing loads on scale tracks, and in the many short movements around the mill.

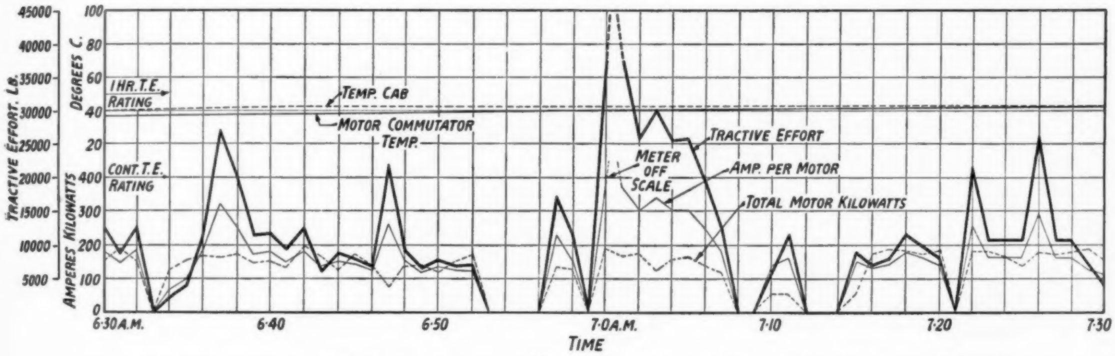
Economy

The prime mover of the oil-electric locomotive is a diesel engine with a thermal efficiency of approximately 33 per cent., or 25-27 per cent. at the driving wheels. In contrast, the average steam switcher with firebox, boiler and steam cylinders has an overall thermal efficiency of only 3-6 per cent. at the driving wheels. The saving in fuel economy is at once apparent, and varies relatively with the local cost of oil and coal fuel. In the present steel mill installations, the 300-b.h.p. oil-electric is operated with from 4-7 U.S. gallons of fuel oil per locomotive hour at a cost of about 24-42 cents per hour. In this same service the previous steam locomotive consumed from 600-700 lb. of coal at a cost of about $1·20 per locomotive hour.

In service of this nature the oil-electric has shown an oil-engine load factor of from 18 to 24·5 per cent. and from

* In a paper read before the National Metal Congress held in conjunction with the American Society of Mechanical Engineers.





Electrical and tractive effort demands upon 300 b.h.p. oil-electric locomotive in steel mill service

6·5 to 8 kWh. generated per U.S. gallon of fuel oil, corresponding to an average fuel cost of approximately four mills per kWh. generated. The lubricating oil consumption varies from 2,500-3,500 rated oil-engine horse-power hours per gallon, and further reduction in lubricating oil cost is now obtainable by the use of continuous centrifuges in the lubricating oil system.

Availability

As regards availability for service, the modern steam locomotive seldom produces an average greater than 40 to 45 per cent. in railroad yard service. Due to their smaller and more compact organisation, increased shop facilities per locomotive, and speedier handling of repairs in the shop, the steel mills are able to obtain a greater utilisation of their steam locomotives. Records from a large number of plants show a steam availability of not more than 55-60 per cent. The availability for service of an oil-electric locomotive is considerably higher, due to the reduction in hostling service and inspections necessary, and to the greater reliability between shoppings. In the present steel mill applications an availability of from 87·5 to 93·5 per cent. has been shown, with regular eight-hour inspection periods every seven days.

Hostling and Maintenance

The loss of time necessitated by cleaning fires, coaling tenders, taking water, washing boilers, and frequent inspections has been greatly reduced by the oil-electric locomotive, whose hostling service requires approximately 7-15 min. per day to take on fuel, water and sand. The elimination of such steam auxiliaries is also a possibility in some mills, offering cleaner and more attractive engine house facilities.

The oil-electric is a simple locomotive. There are fewer parts to repair, the parts are smaller and are easier and less expensive to handle. With greater availability for service, there are fewer locomotives to consider, so that the present average steel mill shop facilities and equipment may be continued without further heavy investment. Over a period of one year one mill showed an average repair cost per locomotive hour of 56 cents for the oil-electric, as against $1·07 for the former steam equipment. The repair costs cover both running repairs and classified or major repairs, and the service so far obtained with oil-electric locomotives would indicate that they will continue to be maintained throughout their life for approximately 50 per cent. of the repair cost of steam equipment.

Track Upkeep

With motors geared to each driving axle, the oil-electric locomotive produces a more uniform torque at the driving wheels, at the same time eliminating the pound on rails and switches from side rods and counterweights. The result is less wear on tracks, trestles, and bridges, with decreasing track maintenance costs. This fact has been noted from casual observation, and it is hoped that concrete figures will be available as more locomotives are placed in service. With power on each axle, the locomotive can help to pull itself back on to the track, saving both time and labour in cases of derailment.

Noise and Smoke

Although the elimination of noise and smoke is of minor importance in steel mill service, still it has its advantages in safety and cleanliness. It is of increasing value in plants where the products of combustion, accompanying the steam locomotive, are detrimental to the perfection of some products or processes of manufacture, particularly where switching movements must be made inside buildings.

Safety

Under the present increase in the rate of steel production, no mill need be cautioned regarding safety of operation. The oil-electric locomotive may be operated from either end of the cab by a single operator, and the following report of the safety committee of one mill on such operation may prove interesting:

(1) The steam locomotive often gives out such a quantity of steam and smoke that the switchman is screened from view of the cab, and the locomotive must stop. This never occurs with the oil-electric.

(2) The steam locomotive driver often receives signals from the switchman through his fireman. This relaying of signals could easily cause confusion. With the oil-electric, the operator always receives the instructions direct from the switchman.

(3) The operation of the oil-electric is less fatiguing than is that of the steam locomotive, because there is no heavy reverse lever to work. Therefore, the oil-electric operator would be more alert at the end of a turn.

(4) The hazard of operation is reduced from two men on the steam to one on the oil-electric. In case of a wreck of the oil-electric, there is only one man to leave the locomotive.

(5) With the steam locomotive, the coupling of buggies and cars is never seen by the engineer, and very often the switchman is out of sight between the buggies and locomotive while he is adjusting the coupling. With the oil-electric, the coupling on the head end is always done in sight of the operator.

Multiple Operation

Multiple-unit control has been developed and applied to the oil-electric locomotives at the Ashland Plant, thus permitting the operation of two or more locomotives as an articulated unit with a single crew. One man can operate the articulated unit from any one of the driving cabs, and control the full power of the combined power plants simultaneously from one throttle. This feature is of benefit in some mills where the greater percentage of the switching can be performed by a uniform size of locomotive, and where the remaining intermittent heavier service can be handled by coupling two or more of these units together under multiple control, with resulting standardisation in locomotive operation and maintenance.

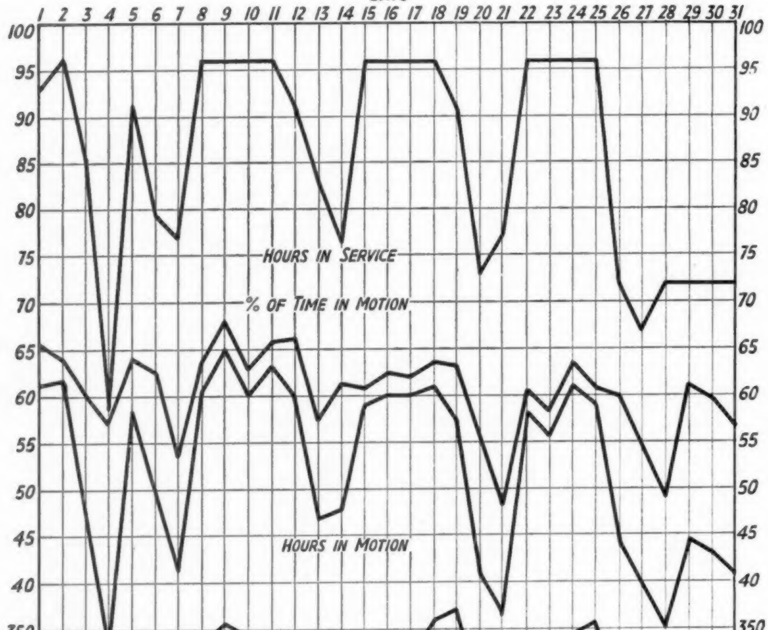
Operating Records

In determining the size of oil-electric locomotive for mill service, it is advisable to establish, if possible, the hardest cycle of work that the locomotive must perform, and how frequently this cycle is liable to occur.

A test was made on one of the locomotives at the Ashland Plant, the cycle occurring on what is termed their "standard yard job." The locomotive had been working on this job several days before the test was made. The temperatures recorded at the beginning represent those that prevail most of the time, while the maximum temperatures recorded represent peaks, the duration of which is not likely to exceed that shown.

It is of interest to note that during the 4 hr. 21 min. of the test, the average oil engine load factor was 32·8 per cent. This is considerably higher than the normal load factor of 23·5 per cent. for this same job, and very much higher than the load factor for the same sized locomotive in railroad float yard service, which averages from 8 to 13 per cent.

A study was also made of the speed attained by the oil-electric locomotive on various assignments in the mill. The speeds attained on the open-hearth charging and open-hearth heat run never exceed 18 m.p.h. and rarely 15 m.p.h., and then only for a fraction of a minute at a time. The speeds attained on the blast furnace and standard yard run are higher, and speedometer readings were taken every minute for four hours. The results are shown on the speed-time curve.



Curves showing hours of service, hours of motion, and fuel consumption of four 300 b.h.p. locomotives

Operating Costs

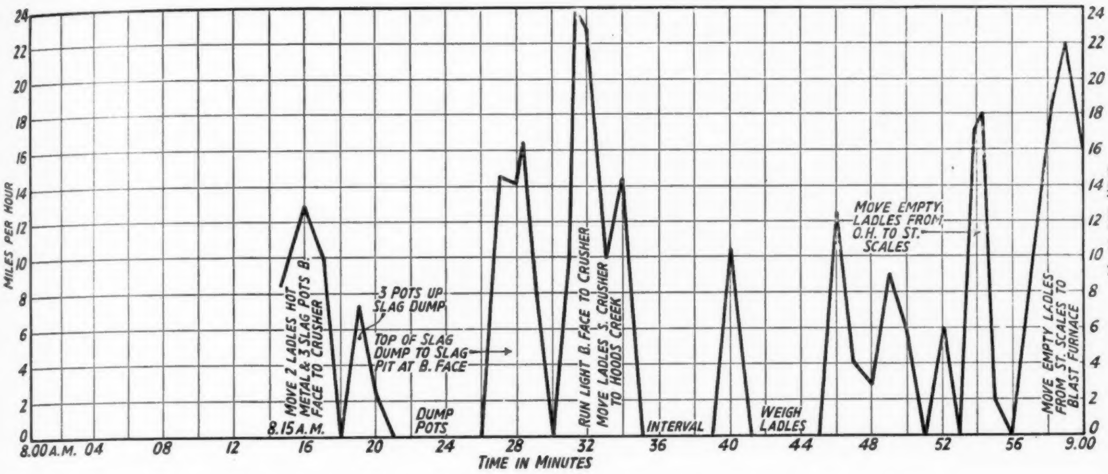
It is evident from an analysis of the data submitted by the railroads on oil-electric locomotive operating costs that there is a lack of consistency of the returns in several instances. This is due to the difficulties confronting rail transportation companies in segregating the details of operation for a particular type of equipment. The industrial organisations have not had to contend with such difficulties, and have been able to follow the locomotive operation more closely, and it is believed that the data thus obtained in steel mill service give a more reliable record of the actual operating results.*

The operating costs are segregated under the items of:—

1. Power, including fuel, lubricating oil, and waste, water, supplies, and engine-house expense.
2. Labour, including enginemen and ground men.
3. Maintenance, including both running repairs and classified repairs or main shopping.
4. Capital charges, including interest, depreciation, and possibly superintendence.

---

* Corresponding detailed operating costs relating to 23 locomotives on nine U.S.A. railroads, as collected by the sub-committee of the American Railway Association reporting on "Development and Use of Oil-Electric Locomotives," are given in the article "Heavy Shunting Results" on pages 702-703 of this Supplement.



Speed-time curve of 300 b.h.p. locomotive on blast-furnace run ; first portion

The operating cost records of the oil-electric locomotives in steel mill service to date are as follow:—

Plant A

Operating cost in dollars and cents per locomotive-hours over a period of one year. Oil-electric locomotives assigned, 4:—

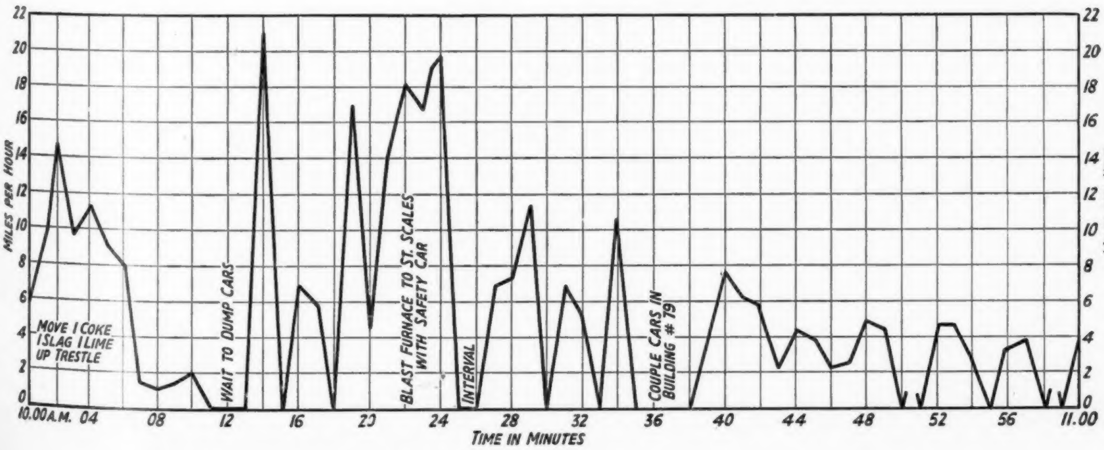
	Oil-Electric $	Steam. $
1. *Power*—		
Fuel	0·2311	1·3081
Water	negligible	0·0247
Lubrication and waste	0·0581	0·0393
Steam coal tower	—	0·0685
2. *Labour*—		
Enginemen	0·8937	1·7124
3. *Maintenance*—		
Repairs / Engine-house expense / Loco. supplies	1·78	2·7118
4. *Capital charges*—		
General works expense	0·4186	0·4540
5. *Miscellaneous*—		
Car and loco. rentals	0·1070	0·0458
Safety and accident	0·1150	0·1430
Engineering and drafting	0·0250	0·0136
Total Cost of Operation—		
Per loco.-hour	3·6285	6·5212
Saving oil-electric per loco.-hour	2·8927	—

Plant B

Operating cost in dollars and cents per locomotive-hour over a period of one year. Oil-electric locomotives assigned, 4:—

	Oil-Electric $	Steam $
1. *Power*—		
Fuel	0·365	1·210
Water	negligible	—
Lubrication	included in supplies	
Loco. supplies	0·080	0·020
Engine house	0·205	0·795
2. *Labour*—		
Enginemen, ground men	1·660	3·310
3. *Maintenance*—		
Repairs	0·560	1·070
4. *Capital Charges*—		
Interest	0·505	0·115
Depreciation	0·815	0·115
Superintendence	0·895	1·065
Total Cost of Operation—		
Per loco-hour	5·085	7·700
Saving oil-electric per loco.-hour	2·615	—

Since the origin of oil-electric locomotives in the United States, an opportunity has been presented of analysing the cost of operation of steam locomotives in steel-mill switching service throughout the country. A comparison



Speed-time curve of 300 b.h.p. locomotive on blast-furnace run ; second portion

of the information obtained from these two sources is significant. Table I was compiled from the 41st Annual Report of the Interstate Commerce Commission, and covers the average cost of operation of 10,728 steam locomotives in yard switching service on Class I railroads. Table II was obtained from 13 different steel plants throughout the country, and covers the average operating cost of approximately 108 steam locomotives in steel-mill switching. These locomotives include both 0-6-0 and 0-8-0 tender types, ranging in size from 47 to 107 tons on drivers and in tractive effort from 23,000 to 48,000 lb.

Table I

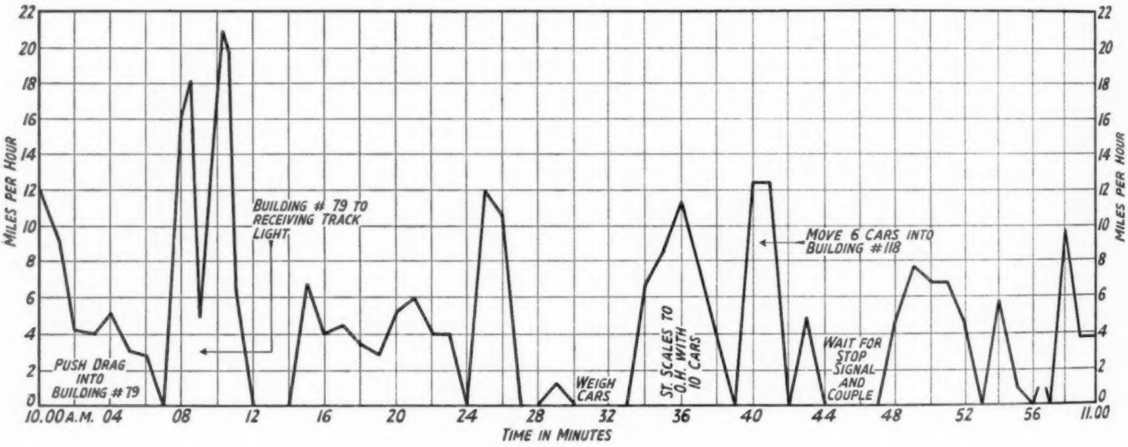
Steam locomotives, all regions; yard switching service.

	Loco.-Hour $
1. *Power*—	
(*a*) Fuel	1·1880
(*b*) Water	0·0828
(*c*) Lubrication	0·0240
(*d*) Loco. supplies	0·264
(*e*) Engine-house expense	0·5562
2. *Labour*—	
(*a*) Engine men	1·6680
(*b*) Train men	—
3. *Maintenance*—	
(*a*) Repairs	1·5960
Total Expenditure	5·1414

Remarks.—(1) Number of locomotives, 10,728; (2) coal, $2·569 per U.S. ton; (3) 807·6 lb. coal per hour.

continue unless it is economically sound and mechanically practicable. After five years' actual service it can be justly assumed that these two conditions have been successfully met. The principal argument against the oil-electric locomotive generally revolves around the question of first cost per unit, which varies from 2·25 to 2·75 times that of an equivalent steam locomotive. The steam locomotive, however, was faced with this same objection in its early stages, and it was only after many years of determination that progress was achieved.

Faced with more expensive material and workmanship, the oil-electric manufacturers are not ignoring the first cost problem. Efforts are being made in this direction by adhering to simplicity throughout the entire locomotive design. Increasing production also offers the possibility of decreasing cost of manufacture, with resultant lower first cost. In the end, however, it is durability and reliability that are all-important; and if a piece of machinery will continue to deliver a profitable return on the investment, the first cost is not primarily essential. The oil-electric locomotive offers great promise and is to-day a most serious development. It is attracting increasing attention on the part of both railroad and industrial transportation departments, and is a factor which merits a closer and more comprehensive study on the part of both manufacturers and users.



Speed-time curve of 300 b.h.p. locomotive on standard run

Table II

Steam locomotives, steel mill service; yard switching service. Size of locomotives, 47 to 107 tons; type 0-6-0 and 0-8-0; T.E., 23,000-48,000 lb.

	Loco.-Hour $
1. *Power*—	
(*a*) Fuel	1·1340
(*b*) Water	0·0507
(*c*) Lubrication	0·0313
(*d*) Loco. supplies	0·1078
(*e*) Engine-house expense	0·4582
2. *Labour*—	
(*a*) Engine men	1·5670
(*b*) Train men	—
3. *Maintenance*—	
(*a*) Repairs	1·0832
Total Expenditure	4·4322

Remarks.—(1) Number of locomotives, 108; (2) number of plants, 13; (3) coal, $3·971 per U.S. ton; (4) 570 lb. coal per hour.

Certainly no mechanical development with such far-reaching possibilities in rail motive power application will

A summary of a test on a 300 b.h.p. oil-electric locomotive, part of which is shown graphically on page 697, is given below.

SUMMARY OF TEST

Fuel and Kilowatt-Hour Meter Readings

Fuel reading start test	101 gal.
Fuel reading finish test	65 ,,
Fuel consumed	36 ,,
kW. hour meter reading start test	3,416
kW. hour meter reading finish test	3,697
kW. hours generated	281
Duration of test	4 hr. 21 min.
Fuel consumption gallons per hour	8·4
kW. hours generated per gallon of fuel	7·8
Per cent. load factor	32·8

Nature of Work

5.39 to 6.52 a.m.	Switching, building No. 118, and taking 19 cars 850 tons to scales.
6.57 to 7.20 ,,	Weighing cars from building No. 118.
7.22 to 8.43 ,,	Putting away cars from building No. 118; switching incoming loads and weighing.
8.51 to 9.15 ,,	Switching stock shed.
8.22 to 10.00 ,,	Miscellaneous switching.

Notes and News

Greek Railcars.—It is reported from Athens that 14 diesel railcars have been ordered from Germany by the Piræus, Athens, Peloponnesus Railway, as a result of permission obtained from the Greek Government to raise a loan for the purpose of renewing the rolling stock. It is believed that payment will not be made in cash, but in kind.

High-Power Indian Locomotives.—Sir W. G. Armstrong, Whitworth & Co. (Engineers) Ltd. has recently secured an order for two 1,300 b.h.p. broad-gauge diesel-electric locomotives for working the Lahore-Karachi mail trains. It is understood that each locomotive will be powered by only one engine set.

Future German Railcar Services.—As a result of the performance put up by the Flying Hamburger and the numerous 300-410 b.h.p. express diesel railcars, the German State Railway has decided to introduce in 1935 similar vehicles on 22 main lines with a total length of 5,760 miles. The average speed of the principal trains will be thereby raised from 43·5 to 63·8 m.p.h. An initial batch of 40 high-speed cars is to be constructed in time for the opening of the summer time-tables next year. A list of the lines affected and the proposed schedules were given in THE RAILWAY GAZETTE for April 6.

Diesel Locomotive in Lamp Factory.—Last year John Fowler & Co. (Leeds) Ltd. delivered to the General Electric Company a small four-wheeled diesel-mechanical shunting locomotive for use in the Osram lamp factory, and this machine is shown in the accompanying illustration. The locomotive operates on the standard gauge and is powered by a 52 b.h.p. Ruston oil engine.

52 *b.h.p. diesel-mechanical locomotive at the Osram lamp works of the General Electric Company*

Diesel Locomotive Tested at Steel Works.—The 15-ton 85 b.h.p. diesel-electric shunting locomotive, which was shown at the last Shipping and Machinery Exhibition by Sir W. G. Armstrong, Whitworth & Co. (Engineers) Ltd., was later tested for some time at the Scunthorpe works of the Frodingham Iron & Steel Co. Ltd. Although small for the work which it was desired to perform, it is understood to have acquitted itself very well.

British Railcar in Branch-Line Work.—The 200 b.h.p. diesel-electric railcar designed and built by the English Electric Company is at present being overhauled at the makers' works after having completed 20,000 miles running. Within the next few days it is to be returned to Burton-on-Trent, where it was at work before being withdrawn for overhaul. This car, which commenced its working life in October last on the Warwick-Daventry-Northampton line of the L.M.S.R., and later ran between Watford and St. Albans, was described in the *Diesel Railway Traction Supplement* for December 29.

Indian Railcar Enquiry.—The Madras & Southern Mahratta Railway are enquiring for six double-bogie diesel-electric railcars to replace steam trains on short-distance services over broad-gauge lines. Tenders are due in at the London office of the company by April 24.

Scandinavian Diesel Railcar.—It is reported that the first diesel railcar in Norway has recently been set to work, and the possibilities of diesel-electric trains on such main lines as that from Oslo to Trondhjem are already being discussed by the Norwegian authorities. High speeds are not contemplated, in view of the curves and gradients.

HEAVY SHUNTING RESULTS

American records show interesting figures

600-*b.h.p.* *Ingersoll-Rand locomotive, Illinois Central Railroad*

A REPORT of great value to engineers studying the question of heavy diesel shunting locomotives has been drawn up by the sub-committee of the American Railway Association considering the "Development and Use of Oil-Electric Locomotives." Covering statistics obtained from 23 locomotives on nine railroads, the report refers to locomotives of 300 to 800 b.h.p. with Ingersoll-Rand and Westinghouse oil engines. The figures of the two makes are not separated, but as was shown in the *Diesel Railway Traction Supplement* for April 21 and May 19, 1933, they do not differ greatly. A brief illustrated description of the 300 and 400 b.h.p. locomotives of both makes will be found in the issue of this Supplement for November 3, 1933, and of the Erie 800 b.h.p. machine in the issue of January 26 last.

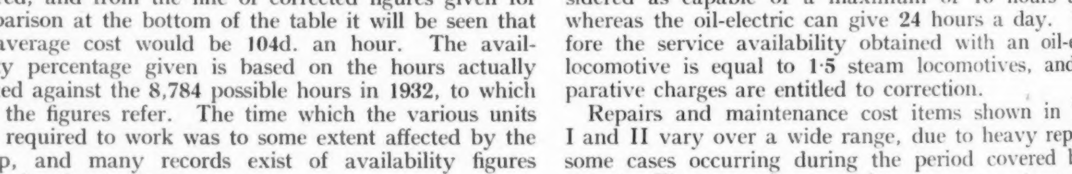
From Table I it will be seen that the average net operating cost of 13 locomotives is 109·55d. an hour. If one-man operation be permitted, the cost will be lowered, and from the line of corrected figures given for comparison at the bottom of the table it will be seen that the average cost would be 104d. an hour. The availability percentage given is based on the hours actually worked against the 8,784 possible hours in 1932, to which year the figures refer. The time which the various units were required to work was to some extent affected by the slump, and many records exist of availability figures approximating to 80-85 per cent.

Various factors govern the economical operation of oil-electric shunting locomotives, as a review of the cost sheets indicates, and to offset the higher initial cost, the service conditions should ensure continuity of operation. A one-man engine crew is also very desirable if the new form of traction is to show appreciable savings over steam units. Depreciation at 4·0 to 4·5 per cent. and interest or fixed charges at 4·5 to 6·0 per cent. constitute items of great importance in the total hourly operating cost, more especially when the steam power which has been replaced has depreciated to nearly salvage value.

If the service life of the steam locomotives has reached a stage where further heavy repairs do not justify the continuance of such old engines in operation, and replacements cannot be effected by other old steam engines, the purchase of new locomotives will be necessary. From the availability standpoint, the steam engine may be considered as capable of a maximum of 16 hours a day, whereas the oil-electric can give 24 hours a day. Therefore the service availability obtained with an oil-electric locomotive is equal to 1·5 steam locomotives, and comparative charges are entitled to correction.

Repairs and maintenance cost items shown in Tables I and II vary over a wide range, due to heavy repairs in some cases occurring during the period covered by the report. These repairs may be necessary at any time between one and three years, and although the first American oil-electric locomotive of this type has been in service over nine years, the sub-committee does not consider that conservative total cost figures which would apply in all cases of heavy shunting operation can yet be given.

Enginehouse expense is an accounting charge that in-

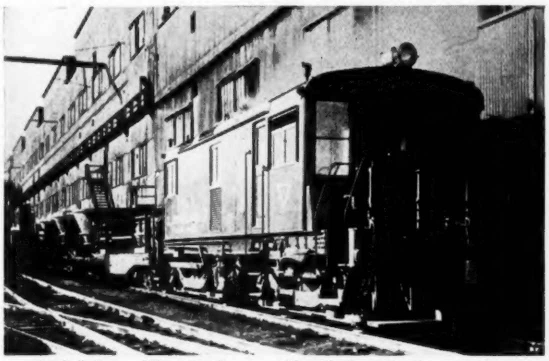


800-*b.h.p.* *Ingersoll-Rand locomotive in shunting service on Erie Railroad*

TABLE I.—OPERATING STATISTICS, 300-b.h.p. OIL-ELECTRIC LOCOMOTIVES

Operating Company:	1	2	3	4	5	11	12	20
Number of locomotives	2	1	2	3	1	1	1	2
Weight per locomotive, lb.	130,000	142,400	131,950	130,000	120,000	132,700	120,000	140,000
Engine horse-power	300	400	300	300	300	300	300	300
Locomotives in service	2	1	2	3	1	1	1	2
No. of men in engine crew	1	2	2	1	1	1	1	1
Months in service	12	11	11	12	12	10	12	12
Hours in service, total for stud	4,973	3,867	8,622	13,062	2,396	1,752	2,619	8,352
Availability per cent.	28	49	54	50	27	24	30	48
kWh. per hour	8·66	?	29·88	26·0	7·76	10·1	10·48	27·41
Fuel oil, gallons per hour	1·50	4·69	3·72	3·28	2·55	1·90	1·41	3·25
Lubricating oil, gallons per hour	0·0416	0·50	0·163	0·124	0·0416	0·0358	0·749	0·14
Cost per hour per locomotive, pence—								
Fuel oil	4·940	13·730	8·165	8·100	6·530	4·170	5·448	5·862
Lubricating oil	1·440	2·473	4·255	4·610	1·813	1·382	2·415	3·348
Other lubrication	0·158	0·282	0·138	—	0·183	0·064	—	—
Repairs	45·300	17·600	34·480	52·320	39·600	8·030	44·420	15·300
Engine-house expense	2·680	60·400	—	—	—	0·532	23·660	—
Other expenses	0·138	0·795	0·588	1·230	0·247	37·470	0·002	0·002
Wages	42·100	80·500	73·650	41·000	41·450	51·400	44·420	37·610
Total operating cost	96·756	175·780	121·276	107·260	89·823	103·048	120·365	62·122
Depreciation	46·000	?	24·600	34·200	37·700	68·950	19·520	15·050
Fixed charges	70·500	?	42·200	42·120	75·480	103·300	69·600	22·595
Gross operating cost	213·256	?	188·076	183·580	203·003	275·298	209·485	99·767
Total operating cost, corrected to one-man crew	96·756	161·550	91·900	107·260	89·823	103·048	120·365	62·122

cludes costs for heating, lighting, water, steam, ash-plant operation, and miscellaneous labour, and the total cost distributed per steam locomotive is chargeable to each oil-electric, although it is known that the actual terminal charges are less. This debits the oil-electric with a higher operating cost than is actually incurred, but it does not appear as if any other method of accounting can be reasonably adopted, as relatively few oil-electrics usually operate alongside a great number of steam units. The adaptability of the oil-electric locomotives as to clearances, concentrated weights, ease of operation over sharp curves, points and crossings in industrial yards, quick acceleration in short hauls, and absence of smoke, is a strong recommendation for their adoption in shunting service, quite apart from fuel economy, especially if the steam locomotives employed have reached replacement point, and no other old engines are available.



300-*b.h.p. Westinghouse diesel-electric locomotive*

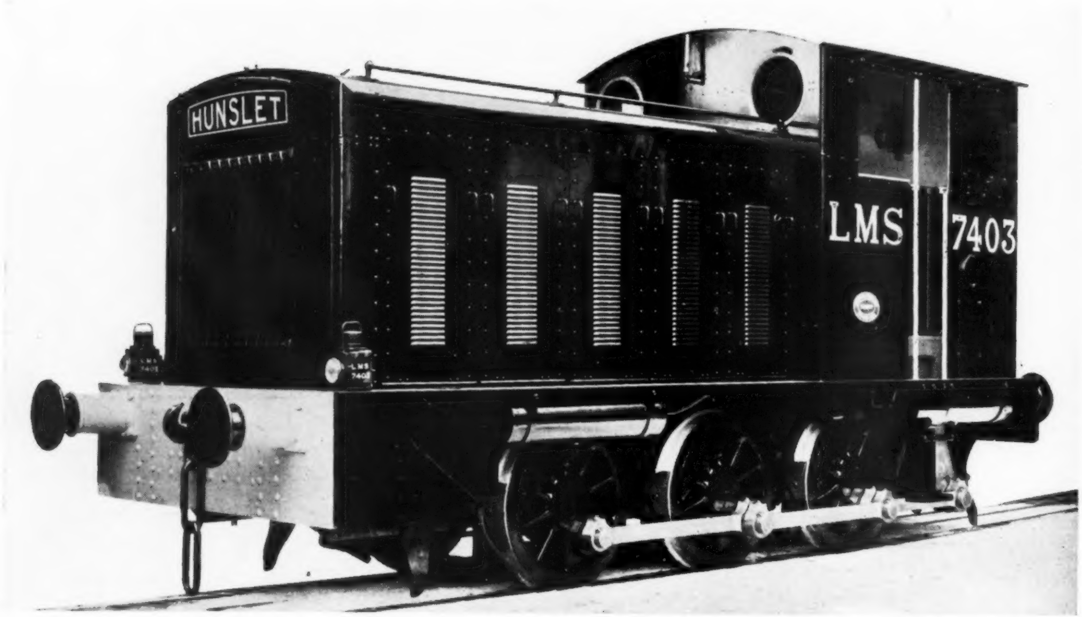
TABLE II.—OPERATING CHARACTERISTICS, 600 AND 800-b.h.p. OIL-ELECTRIC LOCOMOTIVES

Operating Company:	1	4	8	11	11	1
Number of locomotives	2	1	1	2	2*	1
Weight per locomotive, lb.	333,000	216,000	209,500	205,000	248,000	230,000
Engine horse-power	600	600	600	600	300 640 Battery	800
Locomotives in service	2	1	1	2	2	1
No. of men in engine crew	2	1	2	1	2	2
Months in service	11·5	12	10	1·8	11	12
Hours in service, total for stud	9,866	6,878	3,065	1,081	9,044	6,897
Availability per cent.	60·0	78·5	43·0	83·0	57·0	79·0
kWh. per hour	54·0	—	—	51·03	54·89	39·8
Fuel oil, gallons per hour	6·745	6·210	7·485	5·35	6·91	6·48
Lubricating oil, gallons per hour	0·186	0·119	0·122	0·085	0·110	0·10
Cost per hour per locomotive, pence—						
Fuel oil	13·450	15·410	15·260	10·920	13·000	13·180
Lubricating oil	4·175	4·540	4·495	5·500	3·918	3·240
Other lubrication	0·074	—	—	—	0·791	0·050
Repairs	75·610	25·280	69·410	29·290	31·300	28·200
Engine-house expense	2·455	—	26·520	9·820	6·245	1·870
Other expenses	0·415	0·919	0·806	0·716	39·590	0·240
Wages	77·100	42·350	84·050	42·100	85·330	76·000
Total operating cost	173·279	88·499	200·541	98·346	180·174	122·780
Depreciation	40·350	36·410	70·450	26·100	65·900	32·600
Fixed charges	60·500	43·360	96·650	34·610	98·850	48·850
Gross operating cost	274·129	168·269	367·641	159·056	314·924	204·230
Total operating cost, corrected to one-man crew	138·350	88·499	158·550	98·346	137·514	84·78

* Oil-electric-battery locomotives.

THE LATEST BRITISH SHUNTING LOCOMOTIVE

Diesel-geared machine with sleeve-valve engine commences operation in Yorkshire goods yard



150/165 ***b.h.p. diesel-mechanical locomotive***

ANOTHER of the nine diesel shunting locomotives ordered by the L.M.S.R. just over twelve months ago has been delivered during the past week, making a total of four now actually in service in the goods yards of that company. This fourth locomotive is the third constructed by the Hunslet Engine Company, and apart from the engine and primary part of the transmission, is virtually the same as its predecessor, No. **7402**, described in our issue of December **29, 1933**, the wheelbase, weight, frames, cab, &c., being identical. It is now operating in **24**-hr. service in Hunslet goods yard, alongside the two other locomotives built by the Hunslet Engine Company, but we understand that the first of these (see the *Diesel Railway Traction Supplement*, November **3, 1933**) is to be transferred to Chester as soon as No. **7403** is run in.

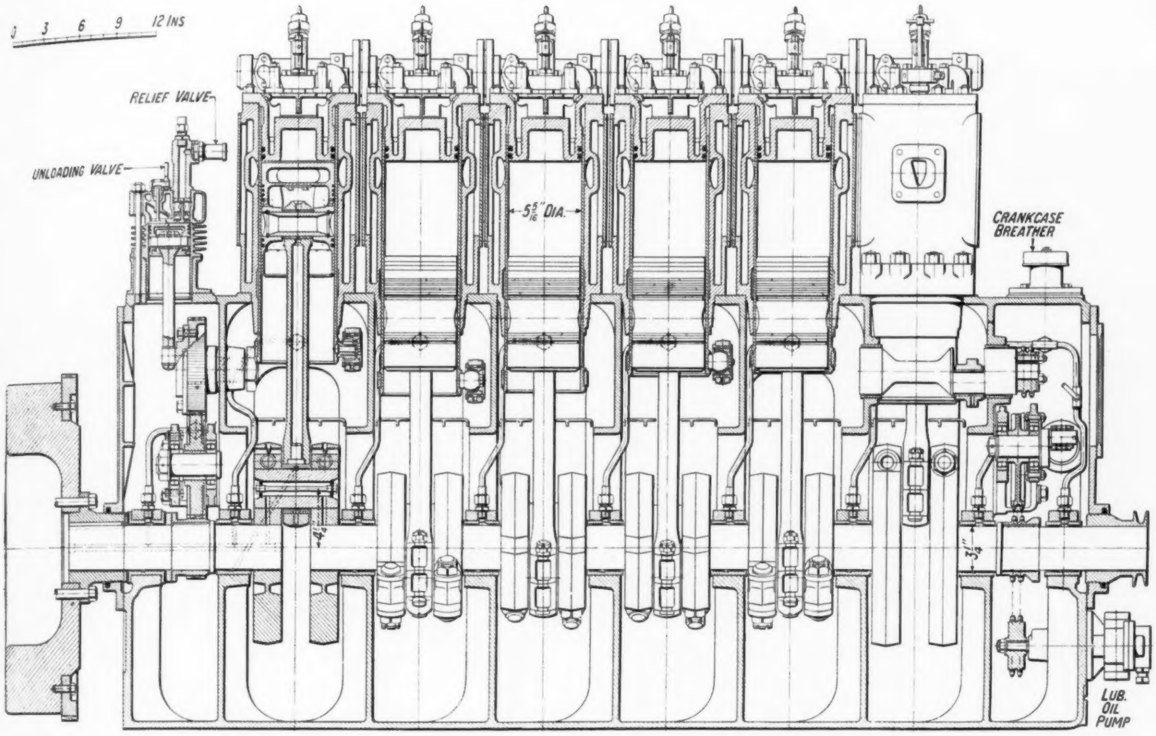
The Engine

A six-cylinder sleeve-valve Brotherhood-Ricardo engine forms the power unit of the locomotive under consideration, and develops **150-165** b.h.p. at **1,200** r.p.m. The admission of air, through Vokes filters, and discharge of exhaust gases to and from each cylinder are controlled by a single cast-iron ported sleeve having a compound rotary motion with vertical and horizontal components. Special provision is made for cooling the exhaust ports, and the inlet ports are arranged tangentially so as to give the air charge a rotational swirl. The single-piece bedplate which carries the crankshaft bearings in double walls of box girder section is extended sideways and machined to fit between the locomotive frames, thus forming a rigid cross stay in which is incorporated the engine sump. The half-speed shaft which operates the sleeve valves is driven by spur gears from the flywheel end of the crankshaft. Lubricating oil is supplied under pressure, along steel pipes, to the crankpins and thence to all working parts, an Auto-Klean strainer being used in the system.

Fuel injection is on the C.A.V.-Bosch system, and the pump is built as a complete unit with the engine governor. A powerful governor, having a vertical shaft at the top of the crankcase, controls the speed within close limits, and the governing is effected by a sliding rod coupled to the governor lever, which causes a partial rotation of the pump plungers and a consequent variation in the amount of fuel by-passed to the pump suction on each stroke.

Because of the rotational swirl of the air charge, which is such an important feature of the Brotherhood-Ricardo design, an atomiser with a single large hole is employed, and is considerably offset in relation to the centre-line of the engine. The cooling water is circulated through a Serck sectional radiator mounted on the front of the engine casing. Air is pulled through the cooler by a fan driven from the main engine. Starting of the engine is carried out by an air motor engaging with the Bendix gear applied to the flywheel. The air is supplied by a single cylinder compressor embodied in the engine, but an auxiliary compressor driven by a Gardner petrol engine is also provided to charge the starting reservoir initially. These starting arrangements have proved very effective in the short time the locomotive has been in actual service.

The transmission of power to the road wheels is by a combination of a Vulcan-Sinclair fluid flywheel and an epicyclic gearbox constructed by David Brown & Sons Ltd., and designed by that firm in conjunction with the Hunslet Engine Company. The hydraulic coupling is

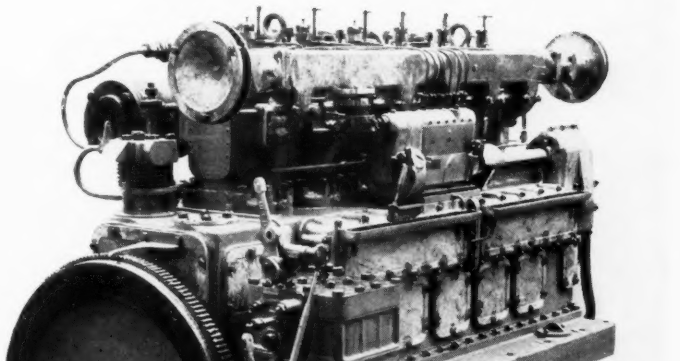


Six-cylinder Brotherhood-Ricardo sleeve-valve engine of the type used in the L.M.S.R. shunting locomotive

carried on the engine crankshaft, and the driving shaft extends to meet the main gearbox drive. A heavy internal expanding brake drum is fitted in order to hold the drag of the coupling while forward or reverse gear is engaged. An exceptionally robust epicyclic brake is necessary for the onerous conditions of heavy shunting work, and for this reason the usual contracting band brake inside the gearbox has been replaced by an internal expanding brake outside the box, and the shaft carrying the drum is sleeved out over the driving shaft. This arrangement outside the gearbox is an improvement on the old type, in which the Ferodo lining had to work in oil, but it prevents the use of more than two speeds. However, it was considered that two speeds were ample for normal shunting work, and the speeds and tractive efforts provided are the same as those of the preceding locomotive, viz., 4·5 and 9·0 m.p.h., and 12,000 and 6,000 lb.

An epicyclic gearbox does not require the Hunslet patent gear-changing mechanism, but apart from this the controls, reversing lever and air-brake handle are simply arranged at each side of the footplate. One hand wheel regulates the throttle and the change of gear, the latter, of course, being effected without any temporary loss of tractive effort at the drawbar. A foot-pedal is fitted to enable the engine throttle to be varied independently of the gears, that is, when the locomotive is stationary. Other fittings included sanding gear, and a hand brake is located at the back of the cab.

This locomotive is to be followed shortly by another Hunslet diesel-mechanical unit of similar design, but of slightly greater horsepower. The engine, of Davey Paxman manufacture, will develop a maximum of 200 b.h.p.



150/165 *b.h.p. Brotherhood-Ricardo engine*

DIESEL ENGINE STARTING

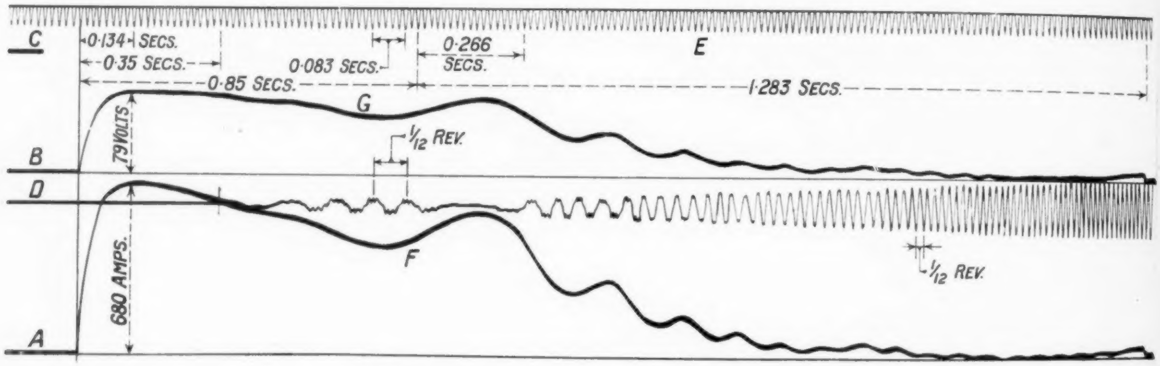
Test records of the power requirements with electric methods

THE respective merits of electric and air starting for railway diesel engines were discussed at some length in the issue of this Supplement for December 1, and the actual power requirements for starting a small engine were given. Oscillograph tests have recently been conducted in America on one of the numerous six-cylinder 300 b.h.p. Ingersoll-Rand four-stroke engines, and the following observations are based on the results published in our American contemporary, the *Railway Mechanical Engineer*. The Ingersoll-Rand engines have six cylinders 10 in. bore by 12 in. stroke and run at 550 r.p.m. They are of a heavy design, and scale 64 lb. per b.h.p.

When it is considered that the time cycle of starting ranges from 1·5 to 2·25 sec. when the engine is warm, and the current, voltage and time values are required for fractions of a second during this cycle, it will be seen that the necessary accuracy would not be possible if direct-reading instruments containing damping features were used. An oscillograph record of a test is shown in the accompanying illustration. The line A indicates zero amperes, B zero battery volts, C open circuit battery volts, and D the revolutions of the speed-indicating alternator. The vertical lines at the top of the record show the 60-cycle timing wave. When the starting motor is thrown across the battery, the rise of current and corresponding drop in voltage are indicated by curves F and G. The voltage measured was that across the battery terminals, and curve G shows the drop in voltage with increase of load, a measure of battery performance. The open-circuit voltage is approximately 114, and when the battery voltage drop is 79, as shown in the illustration, the voltage across the terminals of the generator, which acts as the starting motor, is 35.

When the starting switch is put in, the increase of power is continuous until the engine starts to move. For purposes of calculation, the point at which the engine starts to move is taken as the break-away value, at which point the current reaches 680 amp., the reduction in battery voltage 79, and the voltage available at the starting motor terminals 35.

In the tests under consideration, 0·134 sec. elapsed from the moment current was applied until the engine started to move. From this point the current begins to fall until the first compression stroke is encountered, at which moment the current begins to rise and continues to go up until the top dead centre, when the current falls and the voltage increases until the next piston starts its compression stroke. The revolutions were recorded by means of a small alternator geared to the engine crankshaft with a ratio of four to one. The speed is calculated in conjunction with the 60-cycle timing wave by recording the cycle wave of the alternator, which is a six-pole machine. Each revolution therefore gives three cycles, and as its speed is stepped-up in the ratio of four to one, 12 cycles of the wave represent one revolution of the engine, and the distance between the crests is equivalent to one-twelfth of a revolution.



Oscillograph diagram of electric starting tests

From the revolutions line, D, it will be seen that when the circuit is closed the line remains straight for a period of 0·35 sec., after which it begins to take on the form of a wave. This is the point at which the speed has increased sufficiently to cause the revolution counter to register. Firing begins at 65 r.p.m., 0·85 sec. after the starting circuit has been closed. Observing the revolutions wave at 16 cycles of the timing wave, or approximately 0·266 sec. after firing begins, it will be seen that the engine speed decreases at the moment of firing, as combustion begins before the top dead centre at these low speeds and momentarily retards the acceleration. After firing begins, the speed rapidly increases to 260 r.p.m., which is reached just before power is cut off from the starting motor at 2·133 sec. after power was applied. Acceleration thence up to the rated speed is, of course, extremely rapid.

In the majority of cases the engine would continue to run if the starting power were cut off immediately after firing commenced, but in the particular example tested the control was arranged to keep the starting circuit closed until the engine had reached a speed high enough to build up a pre-determined lubricating oil pressure. The reason for this is that the engine is protected against low lubricating oil pressure by means of an oil-operated switch in the control. The function of this switch must be annulled during starting, and this is accomplished through interlocks on the starting contactor.

The method of starting the engine of diesel-electric locomotives is not always electrical, and in the *Diesel Railway Traction Supplement* for December 1 last the alternative systems were discussed.

on

es to
and
com-
eans
with
con-
the
ine.
its
cles

d
n